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Title:	IMAGING FOR A MACHINE-VISION SYSTEM (Continuation Under 35 U.S.C. 111(a) of PCT US99/15411, filed July 8, 1999)	

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Prior to examination, please amend the above-identified continuation application as follows.

In the Specification

On page 1, after the title, please insert:

–Cross-Reference to Related Application

This application is a continuation under 35 U.S.C. 111(a) of International Patent Application No. PCT/US99/15411, filed July 8, 1999, which claims priority under 119(e) from U.S. Provisional Application SN 60/092,089, filed July 8, 1998, which applications are incorporated herein by reference.--

On page 59, after line 12 and before line 13, please add the following text:

--In summary, the present invention provides a method and apparatus for identifying and handling device tilt in a three-dimensional machine-vision image which is generated from an inspection of a device under test. The device tilt is determined and compensated for, so that various problems previously associated with device tilt are substantially diminished if not entirely eliminated from the device inspection and production line.

It will be apparent to those skilled in the art that the disclosed invention can be modified in numerous ways and can assume many embodiments other than the preferred form specifically set out and described above.

For example, it will be understood by one of ordinary skill in the art that the selection of specific parameters, numbers of samples, tolerances, and so forth is a matter of design and operational optimization and fine tuning and will depend upon the particular environment and

context in which the apparatus and method of the present invention are practiced. In one embodiment the process shown in the flow charts of the Figures and in the computer program listings appended hereto are performed in a different order than that indicated.

It will also be understood that while a preferred embodiment of the invention is described as being implemented in part on a stored program digital computer, the invention may also be implemented, in other embodiments, with special-purpose electronic circuits.

It will be further understood that other embodiments of the invention may be implemented using a different type of voting scheme, such as ballot box memory for example, than that shown herein for determining the most likely amount of tilt in the measured plane.

The following alpha-numbered paragraphs represent various embodiments and combinations according to various aspects of the present invention.

A1. One embodiment of the invention includes a machine-vision head for measuring a three-dimensional geometry of a device having a surface to be measured, including: a projector, the projector including: a first light source having a projection optical axis that intersects the device; a projection-imaging element positioned along the projection optical axis and spaced from the first light source; and a projection-pattern element positioned between the first light source and the projection imaging element along the projection optical axis, the projection-pattern element having a repeating sine-wave light-modulation pattern as measured along a line on the projection-pattern element; and an imager, the imager having a reception optical axis that intersects the device substantially at the projection optical axis.

A2. Some embodiments include the machine-vision head according to alpha-numbered paragraph A1, wherein the projection-pattern element light-modulation pattern includes a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

A3. Some embodiments include the machine-vision head according to alpha-numbered paragraph A2, wherein the first light source includes a elongated incandescent filament having a dimension along a longitudinal axis substantially longer than a width, wherein the longitudinal

axis of the filament is substantially perpendicular to the projection optical axis and substantially parallel to the grid lines of the projection-pattern element.

A4. Some embodiments include the machine-vision head according to alpha-numbered paragraph A2, further including a projection mask having an elongated aperture having a dimension along a length axis substantially longer than a dimension along a width axis perpendicular to the length axis, and wherein the length axis is substantially parallel to the grid lines of the projection-pattern element.

A5. Some embodiments include the machine-vision head according to alpha-numbered paragraph A4, wherein the projection mask limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

A6. Some embodiments include the machine-vision head according to alpha-numbered paragraph A4, further including a projection-mask actuator operable to adjust a position of the projection mask.

A7. Some embodiments include the machine-vision head according to alpha-numbered paragraph A1, further including a light-intensity controller, coupled to receive intensity information regarding light output from the first light source, that outputs a control signal based on a measured intensity of light from the first light source.

A8. Some embodiments include the machine-vision head according to alpha-numbered paragraph A7, wherein the control signal is operatively coupled to the first light source to control light output based on the measured light intensity in a feedback manner.

A9. Some embodiments include the machine-vision head according to alpha-numbered paragraph A7, wherein the control signal is operatively coupled to the imager to control an amount of light received in an imaging cycle of the imager.

A10. Some embodiments include the machine-vision head according to alpha-numbered paragraph A1, further including a condensing imaging element positioned between the first light source and the projection-pattern element along the projection optical axis.

A11. Some embodiments include the machine-vision head according to alpha-numbered paragraph A1, further including a focussing reflector that substantially focusses an image of the first light source adjacent to the first light source.

A12. Some embodiments include the machine-vision head according to alpha-numbered paragraph A11, wherein the reception optical axis is oriented to be at substantially a right angle to a direction of scanning, and the projection optical axis is oriented to be at substantially a forty-five-degree angle to the direction of scanning.

A13. Some embodiments include the machine-vision head according to alpha-numbered paragraph A12, wherein a major plane of the projection-imaging element is oriented substantially perpendicular to the projection optical axis and a major plane of the projection-pattern element is oriented substantially perpendicular to the projection optical axis.

A14. Some embodiments include the machine-vision head according to alpha-numbered paragraph A1, further including a second light source that directs substantially unpatterned light onto the device, the second light source being activated to obtain two-dimensional intensity data about the device from the imager.

A15. One embodiment of the invention includes a machine-vision system for inspecting a device, including: (1) an inspection station, the inspection station including: (a) a projector, the projector including: a first light source having a projection optical axis that intersects the device; a projection-imaging element positioned along the projection optical axis and spaced from the first light source; and a projection-pattern element positioned between the first light source and the projection imaging element along the projection optical axis, the projection-pattern element having a repeating sine-wave light-modulation pattern as measured along a line on the projection-pattern element; and (b) an imager, the imager having a reception optical axis that intersects the device when the inspection station is in operation, the imager maintained in a substantially fixed relationship to the pattern projector, the imager including at least three lines of semiconductor imaging pixels; (2) a scanner mechanism that moves the imager relative to the device such that different portions of the device are successively imaged by the imager, wherein the first light source is activated in conjunction with the imager to obtain three-dimensional device geometry data regarding the device; and (3) a comparator coupled to the imager, the comparator comparing one or more characteristics of the acquired three-dimensional device geometry data with an intended predetermined geometry to produce a signal indicative of any device geometry departure of an actual device geometry from the intended predetermined geometry.

A16. Some embodiments include the system according to alpha-numbered paragraph A15, wherein the projection-pattern element light-modulation pattern includes a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

A17. Some embodiments include the system according to alpha-numbered paragraph A16, wherein the first light source includes a elongated incandescent filament having a dimension along a longitudinal axis substantially longer than a width, wherein the longitudinal axis of the filament is substantially perpendicular to the projection optical axis and substantially parallel to the grid lines of the projection-pattern element.

A18. Some embodiments include the system according to alpha-numbered paragraph A15, further including a projection mask having an elongated aperture having a dimension along a length axis substantially longer than a dimension along a width axis perpendicular to the length axis, and wherein the length axis is substantially parallel to the grid lines of the projection-pattern element.

A19. Some embodiments include the system according to alpha-numbered paragraph A18, wherein the projection mask limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

A20. Some embodiments include the system according to alpha-numbered paragraph A15, further including a light-intensity controller, coupled to receive intensity information regarding light output from the light source, that outputs a control signal based on a measured intensity of light from the light source, wherein the control signal is operatively coupled to the imager to control an amount of light received in an imaging cycle of the imager.

A21. Some embodiments include the system according to alpha-numbered paragraph A15, further including a focussing reflector that substantially focusses an image of the light source adjacent to the light source.

A22. Some embodiments include the system according to alpha-numbered paragraph A15, further including a condensing imaging element positioned between the first light source and the projection-pattern element along the projection optical axis.

A23. Some embodiments include the system according to alpha-numbered paragraph A15, wherein a major plane of the projection-imaging element is oriented substantially perpendicular to the projection optical axis and a major plane of the projection-pattern element is oriented substantially perpendicular to the projection optical axis.

A24. Some embodiments include the system according to alpha-numbered paragraph A15, further including a second light source that directs substantially unpatterned light onto the device, the second light source being activated in conjunction with the imager to obtain two-dimensional intensity data about the device from the imager.

A25. One embodiment of the invention includes a method for measuring a three-dimensional geometry of a device having a surface to be measured, including: projecting patterned light having a spatial-modulation pattern; the projecting pattern light including: (a) projecting substantially unpatterned light, (b) spatially modulating the unpatterened light with a sine-wave spatial modulation pattern to produce spatial-modulation patterned light, and (c) imaging the spatial-modulation patterned light onto the device; scanning the device within the spatial-modulation patterned light; and receiving reflected light from the device into at least three linear imager regions.

A26. Some embodiments include the method according to alpha-numbered paragraph A25, wherein the spatially modulating includes modulating with a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

A27. Some embodiments include the method according to alpha-numbered paragraph A26, wherein the projecting substantially unpatterned light source includes a elongated light beam, wherein a longitudinal axis of the beam is perpendicular to the direction of projection and parallel to the grid lines.

A28. Some embodiments include the method according to alpha-numbered paragraph A26, further including projection masking to an elongated aperture having a length axis substantially greater that a width axis, and wherein the length axis is substantially parallel to the grid lines of the pattern.

A29. Some embodiments include the method according to alpha-numbered paragraph A28, wherein the projection masking limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

A30. Some embodiments include the method according to alpha-numbered paragraph A28, further including a adjusting a position of the projection masking.

A31. Some embodiments include the method according to alpha-numbered paragraph A25, further including generating a light-intensity control signal based on intensity information regarding the projected light.

A32. Some embodiments include the method according to alpha-numbered paragraph A31, further including controlling a light source to control light output based on the measured light intensity in a feedback manner.

A33. Some embodiments include the method according to alpha-numbered paragraph A31, further including controlling an imager to control an amount of light received in an imaging cycle of the imager.

A34. Some embodiments include the method according to alpha-numbered paragraph A25, further including condensing light onto the projection-pattern along the projection optical axis.

A35. Some embodiments include the method according to alpha-numbered paragraph A25, further including reflectively focussing to substantially focus an image of the light source adjacent to the light source.

A36. Some embodiments include the method according to alpha-numbered paragraph A25, wherein the reception optical axis is oriented to be at substantially a right angle to a direction of scanning, and the projection optical axis is oriented to be at substantially a forty-five-degree angle to the direction of scanning.

A37. One embodiment of the invention includes a machine-vision head for measuring a three-dimensional geometry of a device having a surface to be measured, including: a projector, the projector including: a first light source having a projection optical axis that intersects the device; a condensing imaging element positioned along the projection optical axis and spaced from the light source by a distance D_4; a projection imaging element positioned along the

projection optical axis and spaced from the condensing imaging element by a distance D_3; and a projection-pattern element l positioned along the projection optical axis and between the condensing imaging element and the projection imaging element and spaced from the projection imaging element by a distance D_2, the projection-pattern element having a repeating light-modulation pattern that modulates light from the first light source to generate a patterned light useful for determining three-dimensional geometry of the device, wherein a projection-imaging-element-to-device distance D_1 and the distance D_2 are configured to focus an image of projection-pattern element at the surface of device, and the distance D_3 and the distance D_4 are configured so as focus an image of the light source onto the projection-pattern imaging element; and an imager, the imager having a reception optical axis that intersects the device substantially at the projection optical axis, the imager receiving the patterned light as reflected by the device.

A38. Some embodiments include the machine-vision head according to alpha-numbered paragraph A37, wherein the projection-pattern element light-modulation pattern includes a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

A39. Some embodiments include the machine-vision head according to alpha-numbered paragraph A37, wherein the first light source includes a elongated incandescent filament having a dimension along a longitudinal axis substantially longer than a width, wherein the longitudinal axis of the filament is substantially perpendicular to the projection optical axis and substantially parallel to a pattern feature of the projection-pattern element.

A40. Some embodiments include the machine-vision head according to alpha-numbered paragraph A39, further including a projection mask having an elongated aperture having a dimension along a length axis substantially longer than a dimension along a width axis perpendicular to the length axis, and wherein the length axis is substantially parallel to the pattern feature of the projection-pattern element.

A41. Some embodiments include the machine-vision head according to alpha-numbered paragraph A40, wherein the projection-pattern element light-modulation pattern includes a repeating pattern of grid lines having substantially constant density along lines in a direction

parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines, the pattern feature being the grid lines, and wherein the projection mask limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

A42. Some embodiments include the machine-vision head according to alpha-numbered paragraph A40, further including a projection-mask actuator operable to adjust a position of the projection mask.

A43. Some embodiments include the machine-vision head according to alpha-numbered paragraph A37, further including a light-intensity controller, coupled to receive intensity information regarding light output from the first light source, that outputs a control signal based on a measured intensity of light from the first light source.

A44. Some embodiments include the machine-vision head according to alpha-numbered paragraph A43, wherein the control signal is operatively coupled to the first light source to control light output based on the measured light intensity in a feedback manner.

A45. Some embodiments include the machine-vision head according to alpha-numbered paragraph A43, wherein the control signal is operatively coupled to the imager to control an amount of light received in an imaging cycle of the imager.

A46. Some embodiments include the machine-vision head according to alpha-numbered paragraph A37, further including a condensing imaging element positioned between the first light source and the projection-pattern element along the projection optical axis.

A47. Some embodiments include the machine-vision head according to alpha-numbered paragraph A37, further including a focussing reflector that substantially focusses an image of the first light source adjacent to the first light source.

A48. Some embodiments include the machine-vision head according to alpha-numbered paragraph A47, wherein the reception optical axis is oriented to be at substantially a right angle to a direction of scanning, and the projection optical axis is oriented to be at substantially a forty-five-degree angle to the direction of scanning.

A48. Some embodiments include the machine-vision head according to alpha-numbered paragraph A48, wherein a major plane of the projection-imaging element is oriented substantially

perpendicular to the projection optical axis and a major plane of the projection-pattern element is oriented substantially perpendicular to the projection optical axis.

A50. Some embodiments include the machine-vision head according to alpha-numbered paragraph A37, further including a second light source that directs substantially unpatterned light onto the device, the second light source being activated to obtain two-dimensional intensity data about the device from the imager.

A51. One embodiment of the invention includes a machine-vision system for inspecting a device, including: (1) an inspection station, the inspection station including: (a) a projector, the projector including a first light source having a projection optical axis that intersects the device, a condensing imaging element positioned along the projection optical axis and spaced from the light source by a distance D_4, a projection imaging element positioned along the projection optical axis and spaced from the condensing imaging element by a distance D_3, and a projection-pattern element 1 positioned along the projection optical axis and between the condensing imaging element and the projection imaging element and spaced from the projection imaging element by a distance D_2, the projection-pattern element having a repeating light-modulation pattern that modulates light from the first light source to generate a patterned light useful for determining three-dimensional geometry of the device, wherein a projection-imaging-element-to-device distance D_1 and the distance D_2 are configured to focus an image of projection-pattern element at the surface of device, and the distance D_3 and the distance D_4 are configured so as focus an image of the light source onto the projection-pattern imaging element; and (b) an imager, the imager having a reception optical axis that intersects the device substantially at the projection optical axis, the imager receiving the patterned light as reflected by the device; (2) a scanner mechanism that moves the imager relative to the device such that different portions of the device are successively imaged by the imager, wherein the first light source is activated in conjunction with the imager to obtain three-dimensional device geometry data regarding the device; and (3) a comparator coupled to the imager, the comparator comparing one or more characteristics of the acquired three-dimensional device geometry data with an intended predetermined geometry to produce a signal indicative of any device geometry departure of an actual device geometry from the intended predetermined geometry.

A52. Some embodiments include the system according to alpha-numbered paragraph A51, wherein the projection-pattern element light-modulation pattern includes a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

A53. Some embodiments include the system according to alpha-numbered paragraph A52, wherein the first light source includes a elongated incandescent filament having a dimension along a longitudinal axis substantially longer than a width, wherein the longitudinal axis of the filament is substantially perpendicular to the projection optical axis and substantially parallel to the grid lines of the projection-pattern element.

A54. Some embodiments include the system according to alpha-numbered paragraph A51, further including a projection mask having an elongated aperture having a dimension along a length axis substantially longer than a dimension along a width axis perpendicular to the length axis, and wherein the length axis is substantially parallel to the grid lines of the projection-pattern element.

A55. Some embodiments include the system according to alpha-numbered paragraph A54, wherein the projection mask limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

A56. Some embodiments include the system according to alpha-numbered paragraph A51, further including a light-intensity controller, coupled to receive intensity information regarding light output from the light source, that outputs a control signal based on a measured intensity of light from the light source, wherein the control signal is operatively coupled to the imager to control an amount of light received in an imaging cycle of the imager.

A57. Some embodiments include the system according to alpha-numbered paragraph A51, further including a focussing reflector that substantially focusses an image of the light source adjacent to the light source.

A58. Some embodiments include the system according to alpha-numbered paragraph A51, further including a condensing imaging element positioned between the first light source and the projection-pattern element along the projection optical axis.

A59. Some embodiments include the system according to alpha-numbered paragraph A51, wherein a major plane of the projection-imaging element is oriented substantially perpendicular to the projection optical axis and a major plane of the projection-pattern element is oriented substantially perpendicular to the projection optical axis.

A60. Some embodiments include the system according to alpha-numbered paragraph A51, further including a second light source that directs substantially unpatterned light onto the device, the second light source being activated in conjunction with the imager to obtain two-dimensional intensity data about the device from the imager.

A61. One embodiment of the invention includes a method for measuring a three-dimensional geometry of a device having a surface to be measured, including: (a) projecting patterned light having a spatial-modulation pattern; the projecting pattern light including projecting substantially unpatterned light, spatially modulating the unpatterened light with a sine-wave spatial modulation pattern to produce spatial-modulation patterned light, and imaging the spatial-modulation patterned light onto the device; (b) scanning the device within the spatial-modulation patterned light; and (c) receiving reflected light from the device into at least three linear imager regions.

A62. Some embodiments include the method according to alpha-numbered paragraph A61, wherein the spatially modulating includes modulating with a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

A63. Some embodiments include the method according to alpha-numbered paragraph A62, wherein the projecting substantially unpatterned light source includes a elongated light beam, wherein a longitudinal axis of the beam is perpendicular to the direction of projection and parallel to the grid lines.

A64. Some embodiments include the method according to alpha-numbered paragraph A62, further including projection masking to an elongated aperture having a length axis substantially greater that a width axis, and wherein the length axis is substantially parallel to the grid lines of the pattern.

A65. Some embodiments include the method according to alpha-numbered paragraph A64, wherein the projection masking limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

A66. Some embodiments include the method according to alpha-numbered paragraph A65, further including a adjusting a position of the projection masking.

A67. Some embodiments include the method according to alpha-numbered paragraph A66, further including generating a light-intensity control signal based on intensity information regarding the projected light.

A68. Some embodiments include the method according to alpha-numbered paragraph A67, further including controlling a light source to control light output based on the measured light intensity in a feedback manner.

A69. Some embodiments include the method according to alpha-numbered paragraph A68, further including controlling an imager to control an amount of light received in an imaging cycle of the imager.

A70. Some embodiments include the method according to alpha-numbered paragraph A69, further including condensing light onto the projection-pattern along the projection optical axis.

A71. Some embodiments include the method according to alpha-numbered paragraph A61, further including reflectively focussing to substantially focus an image of the light source adjacent to the light source.

A72. Some embodiments include the method according to alpha-numbered paragraph A61, wherein the reception optical axis is oriented to be at substantially a right angle to a direction of scanning, and the projection optical axis is oriented to be at substantially a forty-five-degree angle to the direction of scanning.

A73. One embodiment of the invention includes a machine-vision system for inspecting a device, the machine-vision system including: a light source for propagating light to the device; an image detector that receives light from the device; a light sensor assembly receiving a portion of the light from the light source, the light sensor assembly producing an output responsive to the intensity of the light received at the light sensor assembly; and a controller for controlling the

amount of light received by the image detector, the controller controlling the amount of light within a desired range in response to the output from the light sensor.

A74. Some embodiments include the system of alpha-numbered paragraph A73 wherein the light sensor assembly further includes: a beam splitter positioned between the light source and the device; and a light sensor positioned to receive light from the beam splitter.

A75. Some embodiments include the system of alpha-numbered paragraph A74 wherein the beam splitter filters infrared light from the light source.

A76. Some embodiments include the system of alpha-numbered paragraph A73 further including a power supply which supplies power to the light source, the controller controlling the amount of light received by the image detector by controlling the amount of power output from the power supply.

A77. Some embodiments include the system of alpha-numbered paragraph A73 wherein the controller controls the amount of light received by the image detector by controlling the amount time the image detector receives light to acquire an image.

A78. Some embodiments include the system of alpha-numbered paragraph A73 wherein the image detector further includes an array of imaging pixels, wherein the controller controls the amount of light received by the image detector by controlling the amount time the array of imaging pixels receives light to acquire an image.

A79. Some embodiments include the system of alpha-numbered paragraph A78 further including a memory device which stores correction values for at least one of the pixels in the array of imaging pixels, wherein the value associated with the at least one of the pixels is corrected with a correction value stored in the memory.

A80. Some embodiments include the system of alpha-numbered paragraph A73 wherein the light sensor assembly further includes a photo diode.

A81. One embodiment of the invention includes a machine-vision system for inspecting a device, the machine-vision system including: a light source for propagating light to the device; an image detector that receives light from the device; and a cooling element attached to the imaging device, the cooling element removing heat produced by the image detector to keep the image detector within a selected temperature range.

A82. Some embodiments include the system of alpha-numbered paragraph A81, wherein the cooling element is a thermoelectric semiconductor unit.

A83. Some embodiments include the system of alpha-numbered paragraph A81, wherein the image detector is an array of imaging pixels.

A84. Some embodiments include the system of alpha-numbered paragraph A81, wherein the image detector is an array of semiconductor imaging pixels, the thermoelectric semiconductor unit further including: a temperature sensor for sensing the temperature of the array of semiconductor imaging pixels; a cool portion attached to the array of semiconductor imaging pixels to form a thermally conductive path between the array of semiconductor imaging pixels and the thermoelectric semiconductor unit; a heat rejection portion; and a controller for controlling the amount of power input to the thermoelectric semiconductor to keep the image detector within a selected temperature range.

A85. One embodiment of the invention includes a machine-vision system for inspecting a device, the machine-vision system including: a strobed light source for propagating light to the device; an image detector that receives light from the device, the image detector remaining in a fixed position with respect to the strobed light source; and translation element that moves the strobed light source and image detector with respect to the device.

A86. Some embodiments include the machine-vision system for inspecting a device of alpha-numbered paragraph A85 including a ring light source.

A87. Some embodiments include the machine-vision system for inspecting a device of alpha-numbered paragraph A85 further including a strobed light controller which controls the strobed light source to produce light having a first level and to produce light having a second level, the first level different from the first level.

A88. Some embodiments include the machine-vision system for inspecting a device of alpha-numbered paragraph A86 wherein the image detector further includes: an array of imaging pixels; and an imaging pixel controller which controls the amount of light received by the image detector by controlling the amount time the array of imaging pixels receives light to acquire an image.

A89. Some embodiments include the system of alpha-numbered paragraph A87 further including a memory device which stores correction values for at least one of the pixels in the array of imaging pixels, wherein the value associated with the at least one of the pixels is corrected with a correction value stored in the memory.

A90. Some embodiments include the system of alpha-numbered paragraph A87 further including a memory device which stores a first correction value associated with the first level of light from the strobed light source, and a second correction value associated with the second level of light from the strobed light source for at least one of the pixels in the array of imaging pixels, wherein the values associated with the at least one of the pixels is corrected with the first and second correction values stored in the memory.

A91. Some embodiments include the machine-vision system for inspecting a device of alpha-numbered paragraph A86 wherein the strobed light controller controls the strobed light source to produce light having a first level and alternated with light having a second level.

A92. Some embodiments include the machine-vision system for inspecting a device of alpha-numbered paragraph A86 including a strobed ring light source, the strobed light controller controlling the strobed light source and the strobed ring light source.

A93. Some embodiments include the machine-vision system for inspecting a device of alpha-numbered paragraph A92 wherein the strobed light controller controls the strobed ring light source to strobe alternatively with the strobed light at the first level and at the second level.

A94. Some embodiments include the machine-vision system for inspecting a device of alpha-numbered paragraph A86 wherein the image detector is included of a first line of pixels and a second line of pixels, the machine vision system further including a strobed ring light source, wherein the strobed light controller controls the strobed ring light source to produce light for the first line of pixels and the second line of pixels.

A95. One embodiment of the invention includes a method for acquiring physical information associated with of a device using a machine-vision station having a light source and having an image detector, the method including: projecting light from the light source to the device; receiving light reflected from the device into an image detector; and controlling the amount of light received at the image detector to a value within a desired range.

A96. Some embodiments include the method of alpha-numbered paragraph A95, wherein controlling the amount of light received at the image detector further includes: sensing the projected from the light source; and controlling the amount of power input to the light source in response to the value produced by the sensing step.

A97. Some embodiments include the method of alpha-numbered paragraph A95, wherein the image detector further includes an array of pixels which produce a signal dependent on the length of time the pixel is exposed to the reflected light, wherein the controlling the amount of light received at the image detector further includes sensing the projected from the light source; and controlling the length of time the image detector is exposed to reflected light in response to the value produced by the sensing step.

A98. Some embodiments include the method of alpha-numbered paragraph A95 wherein controlling the amount of light received at the image detector further includes sensing the reflected from the device and controlling the amount of power input to the light source in response to the value produced by the sensing step.

A99. Some embodiments include the method of alpha-numbered paragraph A24 wherein the image detector further includes an array of pixels which produce a signal dependent on the length of time the pixel is exposed to the reflected light, wherein controlling the amount of light received at the image detector further includes sensing the reflected from the device; and controlling the length of time the image detector is exposed to reflected light in response to the value produced by the sensing step.

A100. One embodiment of the invention includes a method for acquiring physical information associated with of a device using a machine-vision station having a light source and having an image detector, the method including projecting light from the light source to the device; receiving light reflected from the device into an image detector; and removing heat produced by the image detector to keep the image detector within a selected temperature range.

A101. Some embodiments include the method of alpha-numbered paragraph A29, wherein removing heat produced by the image detector further includes attaching a thermoelectric semiconductor unit to the image detector.

A102. One embodiment of the invention includes a method for acquiring physical information associated with of a device using a machine-vision station having a light source and having an image detector, the method including fixing the relationship between the light source and the image detector; moving the light source and the image detector with respect to the device; projecting strobed light from the light source to the device; and receiving light reflected from the device into an image detector.

A103. Some embodiments include the method of alpha-numbered paragraph A102 wherein the wherein projecting strobed light from the light source to the device further includes: producing a first level of strobed light from the light source; and producing a second level of strobed light from the light source.

A104. Some embodiments include the method of alpha-numbered paragraph A103 further including producing a strobed light from a ring light.

A105. Some embodiments include the method of alpha-numbered paragraph A104 wherein the wherein projecting strobed light from the light source to the device further includes: producing a first level of strobed light from the light source; producing a second level of strobed light from the light source; and alternating the strobed light of the first level with the strobed light of the second level.

A106. One embodiment of the invention includes a manufacturing system, including: a semiconductor part fabrication unit that fabricates a part for a semiconductor device; and an inspection station, the inspection station further including: (a) a light source projecting light onto the device; (b) an image detector which receives light reflected from the device, the image detector including a plurality of lines of semiconductor imaging pixels; (c) a light sensor assembly receiving a portion of the light from the light source, the light sensor assembly producing an output responsive to the intensity of the light received at the light sensor assembly; and (d) a controller for controlling the amount of light received by the image detector, the controller controlling the amount of light within a desired range in response to the output from the light sensor.

A107. Some embodiments include the manufacturing system of alpha-numbered paragraph A106 wherein the inspection station further includes memory for storing correction values associated with at least one of the pixels in the image detector.

A108. Some embodiments include the manufacturing system of alpha-numbered paragraph A106, wherein the inspection station further includes a light source controller for producing strobed light of a first level and strobed light of a second level.

A109. Some embodiments include the manufacturing system of alpha-numbered paragraph A108 wherein the inspection station further includes a ring light.

A110. Some embodiments include the manufacturing system of alpha-numbered paragraph A106 wherein the inspection station further includes: a ring light; and a ring light controller for strobing the ring light, the ring light controller strobing the ring light for each of the plurality of lines of pixels in the image detector.

A111. One embodiment of the invention includes a machine-vision system for inspecting at least one device, the machine-vision system including a first inspection station, the first inspection station including: a surface for inspecting at least one device, the surface having an opening therein; an inspection device positioned on one side of the inspection surface; and an elevator that places at least one device within the opening in the surface from another side of the inspection surface opposite the one side of the inspection surface, the elevator presenting at least one device to the surface for inspecting at least one device.

A112. Some embodiments include the system of alpha-numbered paragraph A111, wherein the elevator further includes a compartment for holding at least one device, the elevator placing at least one device within the opening in the surface and presenting the device to the surface for inspecting the device.

A113. Some embodiments include the system of alpha-numbered paragraph A112, the first inspection station further including: a light source that propagates light to the device when the device is positioned on the surface for inspecting the device; and an image detector that receives light from the device.

A114. Some embodiments include the system of alpha-numbered paragraph A112 wherein the elevator and the compartment for holding a at least one device is aligned with the opening.

A115. Some embodiments include the system of alpha-numbered paragraph A111 wherein the elevator is aligned with the opening.

A116. Some embodiments include the system of alpha-numbered paragraph A111 further including a first tray for holding at least one device; a first tray for holding at least one device; a tray-transfer mechanism; and a second inspection station, the tray-transfer mechanism operating to move at least one device from the first inspection station to a second inspection station.

A117. Some embodiments include the system of alpha-numbered paragraph A116 wherein the tray-transfer mechanism further includes an inverting mechanism inverts the first tray and the second tray so as to position the at least one device within the second tray so that another side of the at least one device can be inspected.

A118. Some embodiments include the system of alpha-numbered paragraph A116 wherein one side of the at least one device is inspected at the first inspection position and wherein another side of the at least one device is inspected at the second inspection position.

A119. Some embodiments include the system of alpha-numbered paragraph A117 further including: a third inspection station; and a fourth inspection station, the tray-transfer device moving the device between the first and third inspection stations, and between the second and fourth inspection stations.

A120. Some embodiments include the system of alpha-numbered paragraph A119 wherein the inverting mechanism is positioned between the third inspection station and the second inspection station.

A121. One embodiment of the invention includes a machine-vision system for inspecting a plurality of devices positioned within a plurality of device-carrying trays, the machine-vision system including: a first slide clamp adapted to hold a first tray and a second tray, the first slide clamp moving the first tray from a first inspection station to a second inspection station, and moving the second tray from the second inspection station to a flip station; and a second slide clamp adapted to hold a third tray and a fourth tray, the second slide clamp moving the third tray from the flip station to a third inspection station, and moving the fourth tray from the third inspection station to a fourth station.

A122. Some embodiments include the machine-vision system of alpha-numbered paragraph A121 wherein the first slide clamp has two openings therein, each opening sized to receive one of the first device-carrying tray, or the second device-carrying tray, the first slide clamp further including: a registration surface for registering the a surface of one of the first device-carrying tray, or the second device-carrying tray; and a clamp for clamping one of the first device-carrying tray, or the second device-carrying tray in a desired position, the clamp positioned to clamp one of the first device-carrying tray, or the second device-carrying tray with respect to the two openings in the first slide clamp.

A123. Some embodiments include the machine-vision system of alpha-numbered paragraph A121 further including a machine-vision inspection head for scanning the devices within one of the first device-carrying tray, or the second device-carrying tray at the first inspection station, the inspection head further including: a light source that propagates light to the device when positioned on the surface for inspecting the device; and an image detector that receives light from the device.

A124. Some embodiments include the machine-vision system of alpha-numbered paragraph A121 wherein the first tray and a second tray have a substantially rectangular footprint, and wherein the first slide clamp moves at least one of the first tray and the second tray in a direction substantially parallel to the short sides of the at least one of the first tray and the second tray.

A125. Some embodiments include the machine-vision system of alpha-numbered paragraph A124 further including a picker for picking devices which fail inspection from a tray.

A126. Some embodiments include the machine-vision system of alpha-numbered paragraph A125 further including a source of devices that have passed inspection, the picker substituting devices that have passed inspection for the devices that have failed inspection.

A127. Some embodiments include the machine-vision system of alpha-numbered paragraph A125 further including a source of devices that have passed inspection and have not passed inspection, the picker substituting devices that have passed inspection from the source for the devices that have failed inspection to produce a fourth tray filled with devices all of which have not passed inspection.

A128. Some embodiments include the machine-vision system of alpha-numbered paragraph A127 further including: a first location for the devices that have failed inspection; and a second location for devices that have not passed inspection.

A129. One embodiment of the invention includes a machine-vision system for inspecting a tray populated with a plurality of devices, the machine-vision system including: a first inspection station having a first inspection surface; a compartment positioned adjacent the first inspection station, the compartment holding a plurality of trays; and an elevator for elevating at least one of the trays from the compartment to the first inspection surface.

A130. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A19 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays.

A131. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A129 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays, the trays having a rectangular shape, the machine-vision system further including finger elements positioned near the opening, the finger elements engaging the long dimension side of the tray.

A132. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A129 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays, the trays having a rectangular shape, the machine-vision system further including finger elements positioned near the opening, the finger elements engaging the short dimension side of the tray.

A133. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A128 further including a second inspection station having a second inspection surface; an elevator for moving at least one of the trays from the between a first position at the second inspection surface and a second position away from the second inspection surface.

A134. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A129 wherein the compartment further includes: a door which folds from a closed position to an open position; a first guide rail positioned on the inner surface of the door; and a second guide rail positioned on the inner surface of the door, the first guide rail and the second guide rail spaced to receive at least one tray so that the tray can be placed between the first and second guide rails and guided into the compartment.

A135. One embodiment of the invention includes a machine-vision system for inspecting a tray populated with a plurality of devices, the machine-vision system including: an inspection station including an inspection surface; means for determining if at least one of the plurality of devices in a tray at the inspection station does not pass an inspection test; and a failed device station for holding trays which hold devices having devices which have passed inspection and devices which have not passed inspection at which trays are formed in which all of the plurality of devices do not pass inspection.

A136. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A135 further including a first picker for moving at least one of the plurality of devices between the inspection station and the failed device station.

A137. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A136 wherein the first picker for moving at least one of the plurality of devices between the inspection station and the failed device station accommodates differently spaced devices within trays.

A138. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A136 further including a second picker for moving at least one of the plurality of devices between the inspection station and the failed device station.

A139. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A138 wherein the first picker and the second picker for moving at least one of the plurality of devices between the inspection station and the failed device station accommodates differently spaced devices within trays.

A140. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A135 further including a compartment near the failed device station for housing trays in which all of the plurality of devices do not pass inspection.

A141. One embodiment of the invention includes a machine-vision system for inspecting a rectangular tray populated with a plurality of devices, the machine-vision system including: an inspection station including an inspection surface; and means for holding the rectangular tray which engage the sides of the tray with the shorter dimension.

A142. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A141 wherein means for holding the rectangular tray which engage the sides of the tray with the shorter dimension includes a set of pins which engage detents in the shorter side of the tray.

A143. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A142 wherein the pins force the tray to a datum registration surface.

A144. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A141 further including means for moving the rectangular tray in a direction substantially parallel to the shorter dimension of the rectangular tray.

A145. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A144 further including means for inspecting the rectangular tray in a direction substantially parallel to the longer dimension of the rectangular tray.

A146. One embodiment of the invention includes a machine-vision system for inspecting a rectangular tray populated with a plurality of devices, the machine-vision system including: an inspection station including an inspection surface; a 3D inspection device; and a 2D inspection device.

A147. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A146 wherein the 3D device and 2D device inspect the inspection surface synchronously.

A148. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A147 wherein the inspection surface holds a first tray and a second tray.

A149. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A146 wherein the 3D device and 2D device inspect the inspection surface asynchronously.

A150. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A149 wherein the inspection surface holds a first tray and a second tray.

A151. One embodiment of the invention includes a method for acquiring physical information associated with a plurality of devices placed in a tray, the method including: loading at least one tray into a compartment adjacent a first inspection station; and elevating the tray to the first inspection surface.

A152. Some embodiments include the method of alpha-numbered paragraph A151 further including: inspecting a first side of at least one of a plurality of devices within a first tray; moving the first tray to a flip station; and inspecting a second side of at least one of a plurality of devices within the second tray.

A153. Some embodiments include the method of alpha-numbered paragraph A152, further including removing at least one of a plurality of devices from the second tray if the at least one of a plurality of devices fails inspection.

A154. Some embodiments include the method of alpha-numbered paragraph A152 further including replacing at least one of a plurality of devices in the second tray that failed inspection with a device that passed inspection.

A155. One embodiment of the invention includes a machine-vision system for inspecting a device, the machine-vision system including: an initial inspection station, the initial inspection station including: a surface for inspecting the device, the surface having an opening therein; and an

elevator that places the device within the opening in the surface and presents the device to the surface for inspecting the device.

A156. Some embodiments include the system of alpha-numbered paragraph A155 wherein the elevator further includes a compartment for holding a plurality of devices, the elevator placing at least one of the plurality of devices within the opening in the surface and presenting the device to the surface for inspecting the device.

A157. Some embodiments include the system of alpha-numbered paragraph A156, the initial inspection station further including: a light source that propagates light to the device when the device is positioned on the surface for inspecting the device; and an image detector that receives light from the device.

A158. Some embodiments include the system of alpha-numbered paragraph A156 wherein the elevator and the compartment for holding a plurality of devices are aligned with the opening.

A159. Some embodiments include the system of alpha-numbered paragraph A155 wherein the elevator is aligned with the opening.

A160. Some embodiments include the system of alpha-numbered paragraph A155 further including a tray-transfer device that operates to move the device from the initial inspection station to a second inspection station.

A161. Some embodiments include the system of alpha-numbered paragraph A160 further including an inverting mechanism that operates to invert the device so that the another side of the device can be inspected.

A162. Some embodiments include the system of alpha-numbered paragraph A161 wherein one side of the device is inspected in the first inspection position and wherein another side of the device is inspected in the second inspection position.

A161. Some embodiments include the system of alpha-numbered paragraph A160 further including a third inspection station and a fourth inspection station, the tray-transfer device moving the device between the first and third inspection stations, and between the second and fourth inspection stations.

A162. Some embodiments include the system of alpha-numbered paragraph A9 wherein the inverting mechanism is positioned between the third inspection position and the second inspection position.

A163. One embodiment of the invention includes a machine-vision system for inspecting a plurality of devices positioned within a plurality of device-carrying trays, the machine-vision system including:

a first slide clamp for holding at least two trays, the slide clamp moving a first tray from a first inspection station to a second inspection station, and moving a second tray from the second inspection station to a flip station; and

a second slide clamp for holding at least two trays, the slide clamp moving a third tray from the flip station to a third inspection station, and moving a fourth tray from the third inspection station to a fourth station.

A164. Some embodiments include the machine-vision system of alpha-numbered paragraph A163 wherein the first slide clamp has two openings therein, each opening sized to receive a device-carrying tray, the first slide clamp further including:

a registration surface for registering the a surface of the device-carrying tray; and

a clamp for clamping the tray in a desired position, the clamp positioned to clamp the tray with respect to the opening in the slide clamp.

A165. Some embodiments include the machine-vision system of alpha-numbered paragraph A163 further including a machine-vision inspection head for scanning the devices within the trays at the first inspection station, the inspection head further including: a light source that propagates light to the device when positioned on the surface for inspecting the device; and an image detector that receives light from the device.

A166. Some embodiments include the machine-vision system of alpha-numbered paragraph A163 wherein the flip station further includes a mechanism for flipping the devices carried in a tray, the mechanism further including: a first jaw having a surface for receiving a tray; a second jaw having a surface for receiving a tray; a mover for moving the first jaw, a first tray having a plurality of devices, a second tray, and the second jaw into engagement with each other,

the first tray associated with the first jaw and the second tray associated with the second jaw; and a rotator for rotating the first and second jaw.

A167. Some embodiments include the machine-vision system of alpha-numbered paragraph A166 wherein the mover moves the first jaw in a direction substantially perpendicular to the surface for receiving a tray associated with the first jaw.

A168. Some embodiments include the machine-vision system of alpha-numbered paragraph A166 wherein the mover moves the first jaw and the second jaw in a direction substantially perpendicular to the surface for receiving a tray associated with the first jaw.

A169. Some embodiments include the machine-vision system of alpha-numbered paragraph A166 further including a picker for picking devices which fail inspection from a tray.

A170. Some embodiments include the machine-vision systemof alpha-numbered paragraph A168 further including a source of devices that have passed inspection, the picker substituting devices that have passed inspection for the devices that have failed inspection.

A171. One embodiment of the invention includes a machine-vision system for inspecting a plurality of devices and for transferring the plurality of devices from being positioned in a first tray to being positioned in a second tray, the machine-vision system including: a first jaw having a surface for receiving the first tray; a second jaw having a surface for receiving the second tray; a mover for moving the first jaw, the first tray having a plurality of devices, the second tray, and the second jaw into engagement with each other, the first tray associated with the first jaw and the second tray associated with the second jaw; and a rotator for rotating the first and second jaw.

A172. Some embodiments include the machine-vision system of alpha-numbered paragraph A171 further including: a first conveyer for moving the first tray having a plurality of devices therein to the surface of the first jaw; and a second conveyer for moving the second tray having a plurality of devices therein from surface of the second jaw.

A173. Some embodiments include the machine-vision system of alpha-numbered paragraph A172 wherein one of the first or second jaws is capable of holding, in any position, a tray devoid of devices.

A174. One embodiment of the invention includes a machine-vision system for inspecting a tray populated with a plurality of devices, the machine-vision system including: a first inspection

station having a first inspection surface; a compartment positioned adjacent the first inspection station, the compartment holding a plurality of trays; and an elevator for elevating at least one of the trays from the compartment to the first inspection surface.

A175. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A174 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays.

A176. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A174 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays, the trays having a rectangular shape, the machine-vision system further including finger elements positioned near the opening, the finger elements engaging the long dimension side of the tray.

A177. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A174 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays, the trays having a rectangular shape, the machine-vision system further including finger elements positioned near the opening, the finger elements engaging the short dimension side of the tray.

A178. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A174 further including a second inspection station having a second inspection surface; an elevator for moving at least one of the trays from the between a first position at the second inspection surface and a second position away from the second inspection surface.

A179. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A22 wherein the compartment further includes: a door which folds from a closed position to an open position; a first guide rail positioned on the inner surface of the door; a second guide rail positioned on the inner surface of

the door, the first guide rail and the second guide rail spaced to receive at least one tray so that the tray can be placed between the first and second guide rails and guided into the compartment.

A180. One embodiment of the invention includes a method for acquiring physical information associated with a plurality of devices placed in a tray, the method including loading at least one tray into a compartment adjacent a first inspection station; and elevating the tray to the first inspection surface.

A181. Some embodiments include the method of alpha-numbered paragraph A180 further including inspecting a first side of a device within a first tray; moving the tray to a flip station; flipping the devices and placing the flipped devices within a second tray; and inspecting a second side of the device within the second tray.

A182. Some embodiments include the method of alpha-numbered paragraph A181, further including removing a device from the second tray if it fails inspection.

A183. Some embodiments include the method of alpha-numbered paragraph A181, further including replacing a device in the second tray that failed inspection with a device that passed inspection.

A184. One embodiment of the invention includes a machine-vision system for inspecting a plurality of devices and for inverting the plurality of devices from being positioned in a first tray, the machine-vision system including: a first jaw having a surface for receiving the first tray; a second jaw having a surface; a mover for moving the first jaw, the first tray having a plurality of devices, and the second jaw into engagement with each other, the first tray associated with the first jaw; and a rotator for rotating the first and second jaw.

A185. Some embodiments include the machine-vision system of alpha-numbered paragraph A184 further including: a first conveyer for moving the first tray having a plurality of devices therein to the first jaw; and a second conveyer for moving the first tray having a plurality of devices therein from the first jaw.

A186. Some embodiments include the machine-vision system of alpha-numbered paragraph A184 wherein the first jaw is capable of holding, in any position, a tray devoid of devices.

A187. Some embodiments include the machine-vision system of alpha-numbered paragraph A184 further including: a slider for transferring the inverted devices from the second jaw into the first tray.

A188. One embodiment of the invention includes a machine-vision system for inspecting at least one device, the machine-vision system including: a first inspection station, wherein the first inspection station includes a surface for inspecting at least one device, the surface having an opening therein; an inspection device positioned on one side of the inspection surface; and an elevator that places at least one device within the opening in the surface from another side of the inspection surface opposite the one side of the inspection surface, the elevator presenting at least one device to the surface for inspecting at least one device.

A189. Some embodiments include the system of alpha-numbered paragraph A188 wherein the elevator further includes a compartment for holding at least one device, the elevator placing at least one device within the opening in the surface and presenting the device to the surface for inspecting the device.

A190. Some embodiments include the system of alpha-numbered paragraph A189, the first inspection station further including a light source that propagates light to the device when the device is positioned on the surface for inspecting the device; and an image detector that receives light from the device.

A191. Some embodiments include the system of alpha-numbered paragraph A189 wherein the elevator and the compartment for holding a at least one device is aligned with the opening.

A192. Some embodiments include the system of alpha-numbered paragraph A188 wherein the elevator is aligned with the opening.

A193. Some embodiments include the system of alpha-numbered paragraph A188 further including a first tray for holding at least one device; a first tray for holding at least one device; a tray-transfer mechanism; and a second inspection station, the tray-transfer mechanism operating to move at least one device from the first inspection station to a second inspection station.

A194. Some embodiments include the system of alpha-numbered paragraph A193 wherein the tray-transfer mechanism further includes an inverting mechanism inverts the first tray and the

second tray so as to position the at least one device within the second tray so that another side of the at least one device can be inspected.

A195. Some embodiments include the system of alpha-numbered paragraph A193 wherein one side of the at least one device is inspected at the first inspection position and wherein another side of the at least one device is inspected at the second inspection position.

A196. Some embodiments include the system of alpha-numbered paragraph A194 further including a third inspection station; and a fourth inspection station, the tray-transfer device moving the device between the first and third inspection stations, and between the second and fourth inspection stations.

A197. Some embodiments include the system of alpha-numbered paragraph A195 wherein the inverting mechanism is positioned between the third inspection station and the second inspection station.

A198. One embodiment of the invention includes a machine-vision system for inspecting a plurality of devices positioned within a plurality of device-carrying trays, the machine-vision system including: a first slide clamp adapted to hold a first tray and a second tray, the first slide clamp moving the first tray from a first inspection station to a second inspection station, and moving the second tray from the second inspection station to a flip station; and a second slide clamp adapted to hold a third tray and a fourth tray, the second slide clamp moving the third tray from the flip station to a third inspection station, and moving the fourth tray from the third inspection station to a fourth station.

A199. Some embodiments include the machine-vision system of alpha-numbered paragraph A198 wherein the first slide clamp has two openings therein, each opening sized to receive one of the first device-carrying tray, or the second device-carrying tray, the first slide clamp further including: a registration surface for registering the a surface of one of the first device-carrying tray, or the second device-carrying tray; and a clamp for clamping one of the first device-carrying tray, or the second device-carrying tray in a desired position, the clamp positioned to clamp one of the first device-carrying tray, or the second device-carrying tray with respect to the two openings in the first slide clamp.

A200. Some embodiments include the machine-vision system of alpha-numbered paragraph A198 further including a machine-vision inspection head for scanning the devices within one of the first device-carrying tray, or the second device-carrying tray at the first inspection station, the inspection head further including: a light source that propagates light to the device when positioned on the surface for inspecting the device; and an image detector that receives light from the device.

A201. Some embodiments include the machine-vision system of alpha-numbered paragraph A198 wherein the first tray and a second tray have a substantially rectangular footprint, and wherein the first slide clamp moves at least one of the first tray and the second tray in a direction substantially parallel to the short sides of the at least one of the first tray and the second tray.

A202. Some embodiments include the machine-vision system of alpha-numbered paragraph A201 further including a picker for picking devices which fail inspection from a tray.

A203. Some embodiments include the machine-vision system of alpha-numbered paragraph A202 further including a source of devices that have passed inspection, the picker substituting devices that have passed inspection for the devices that have failed inspection.

A204. Some embodiments include the machine-vision system of alpha-numbered paragraph A202 further including a source of devices that have passed inspection and have not passed inspection, the picker substituting devices that have passed inspection from the source for the devices that have failed inspection to produce a fourth tray filled with devices all of which have not passed inspection.

A205. Some embodiments include the machine-vision system of alpha-numbered paragraph A204 further including: a first location for the devices that have failed inspection; and a second location for devices that have not passed inspection.

A206. One embodiment of the invention includes a machine-vision system for inspecting a tray populated with a plurality of devices, the machine-vision system including: a first inspection station having a first inspection surface; a compartment positioned adjacent the first inspection station, the compartment holding a plurality of trays; and an elevator for elevating at least one of the trays from the compartment to the first inspection surface.

A207. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A206 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays.

A208. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A206 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays, the trays having a rectangular shape, the machine-vision system further including finger elements positioned near the opening, the finger elements engaging the long dimension side of the tray.

A209. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A206 wherein the first inspection surface has an opening therein, the opening accommodating one of the plurality of trays, the trays having a rectangular shape, the machine-vision system further including finger elements positioned near the opening, the finger elements engaging the short dimension side of the tray.

A210. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A208further including a second inspection station having a second inspection surface; an elevator for moving at least one of the trays from the between a first position at the second inspection surface and a second position away from the second inspection surface.

A211. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A19 wherein the compartment further includes: a door which folds from a closed position to an open position; a first guide rail positioned on the inner surface of the door; and a second guide rail positioned on the inner surface of the door, the first guide rail and the second guide rail spaced to receive at least one tray so that the tray can be placed between the first and second guide rails and guided into the compartment.

A212. One embodiment of the invention includes a machine-vision system for inspecting a tray populated with a plurality of devices, the machine-vision system including: an inspection

station including an inspection surface; means for determining if at least one of the plurality of devices in a tray at the inspection station does not pass an inspection test; and a failed device station for holding trays which hold devices having devices which have passed inspection and devices which have not passed inspection at which trays are formed in which all of the plurality of devices do not pass inspection.

A213. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A212 further including a first picker for moving at least one of the plurality of devices between the inspection station and the failed device station.

A214. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A213 wherein the first picker for moving at least one of the plurality of devices between the inspection station and the failed device station accommodates differently spaced devices within trays.

A215. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A212 further including a second picker for moving at least one of the plurality of devices between the inspection station and the failed device station.

A216. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A215 wherein the first picker and the second picker for moving at least one of the plurality of devices between the inspection station and the failed device station accommodates differently spaced devices within trays.

A217. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A215 further including a compartment near the failed device station for housing trays in which all of the plurality of devices do not pass inspection.

A218. One embodiment of the invention includes a machine-vision system for inspecting a rectangular tray populated with a plurality of devices, the machine-vision system including: an inspection station including an inspection surface; and a holder mechanism that holds the rectangular tray and engages the sides of the tray with the shorter dimension.

A219. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A218 wherein means for holding the rectangular tray which engage the sides of the tray with the shorter dimension includes a set of pins which engage detents in the shorter side of the tray.

A220. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A219 wherein the pins force the tray to a datum registration surface.

A221. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A218 further including means for moving the rectangular tray in a direction substantially parallel to the shorter dimension of the rectangular tray.

A222. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A34 further including means for inspecting the rectangular tray in a direction substantially parallel to the longer dimension of the rectangular tray.

A223. One embodiment of the invention includes a machine-vision system for inspecting a rectangular tray populated with a plurality of devices, the machine-vision system including: an inspection station including an inspection surface; a 3D inspection device; and a 2D inspection device.

A224. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A223 wherein the 3D device and 2D device inspect the inspection surface synchronously.

A225. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A224 wherein the inspection surface holds a first tray and a second tray.

A226. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A225 wherein the 3D device and 2D device inspect the inspection surface asynchronously.

A227. Some embodiments include the machine-vision system for inspecting a tray populated with a plurality of devices of alpha-numbered paragraph A226 wherein the inspection surface holds a first tray and a second tray.

A228. One embodiment of the invention includes a method for acquiring physical information associated with a plurality of devices placed in a tray, the method including: loading at least one tray into a compartment adjacent a first inspection station; and elevating the tray to the first inspection surface.

A229. Some embodiments include the method of alpha-numbered paragraph A228 further including: inspecting a first side of at least one of a plurality of devices within a first tray; moving the first tray to a flip station; and inspecting a second side of at least one of a plurality of devices within the second tray.

A230. Some embodiments include the method of alpha-numbered paragraph A229, further including removing at least one of a plurality of devices from the second tray if the at least one of a plurality of devices fails inspection.

A231. Some embodiments include the method of alpha-numbered paragraph A229, further including replacing at least one of a plurality of devices in the second tray that failed inspection with a device that passed inspection.

A232. One embodiment of the invention includes a machine-vision system for inspecting a device, the machine-vision system including: a light source that propagates light to the device; a pattern that generates a moire pattern; an image detector that receives light from the device; a light-sensor assembly that receives a portion of the light from the light source and that produces an output responsive to the intensity of the light received at the light-sensor assembly; and a computer and comparison system for manipulating a plurality of outputs from the light-sensor.

A233. Some embodiments include the system of alpha-numbered paragraph A232 wherein the computer and comparison system for manipulating a plurality of outputs from the light-sensor is of sufficient granularity to allow the data obtained to be manipulated to detect various features.

A234. Some embodiments include the system of alpha-numbered paragraph A233 wherein the data can be used to determine coplanarity of features on a device.

A235. Some embodiments include the system of alpha-numbered paragraph A233 wherein the data can be used to determine warpage of a subtrate on a device.

A236. Some embodiments include the system of alpha-numbered paragraph A233 wherein the data can be used to locate random features on a device.

A237. Some embodiments include the system of alpha-numbered paragraph A233 wherein the data can be used to locate features on a device that is randomly situated.

A238. Some embodiments include the system of alpha-numbered paragraph A233 further including: a mover that moves the light source and the device with respect to one another, and a detector that detects the velocity of a the light source with respect to the device.

A239. Some embodiments include the system of alpha-numbered paragraph A238 further including a linear postion encoder for specifying the times at which line scans are taken.

A240. Some embodiments include the system of alpha-numbered paragraph A239 wherein the computer and comparison system measures the distance over which a portion of the device moves over one or more line scans and determines the velocity of the device.

A241. Some embodiments include the system of alpha-numbered paragraph A233 wherein the pattern for generating the moire pattern includes a projection pattern element having a sine-wave element at the light source.

A242. Some embodiments include the system of alpha-numbered paragraph A233 wherein the pattern for generating the moire pattern includes: a first striped pattern; and a second striped pattern, the first striped pattern parallel to and offset from the plane of the second striped pattern, the first striped pattern and the second striped pattern positioned between the light source and the device.

A243. One embodiment of the invention includes a method for acquiring physical information associated with of a device using a machine-vision station having a light source and having an image detector, the method including: projecting light from the light source to the device; producing a moire pattern at the device; gathering data with sufficient granularity such that a device can be randomly placed on an inspection surface for gathering data; and manipulating the gathered data with a computer and comparator to identify various features of the device.

A244. One embodiment of the invention includes a method for acquiring physical information associated with of a device using a machine-vision station having a light source and having an image detector, the method including: projecting light from the light source to the device; producing a moire pattern at the device; gathering data with sufficient granularity such that data can be gathered on randomly placed features on the device positioned on an inspection surface; and manipulating the gathered data with a computer and comparator to identify various features of the device.

A245. Some embodiments include the method of alpha-numbered paragraph A244 wherein manipulating the data can be used to determine coplanarity of a plurality of points on the device.

A246. Some embodiments include the method of alpha-numbered paragraph A244 wherein manipulating the data can be used to determine position of a fiducial mark on a device at two separate times, the method further including calculating the velocity of the device with respect to the light source using the measured position and time.

A247. Some embodiments include the method of alpha-numbered paragraph A244 wherein manipulating the data can be used to determine position of a feature on a device at a first scan time and at a second scan time, the method further including: encoding the position of the feature at the first scan time; encoding the position of the feature at the second scan time; and calculating the velocity of the device with respect to the light source using the measured position and time.

A248. One embodiment of the invention includes a machine-vision head for inspecting a device, including: (a) a pattern projector to provide projected illumination, the pattern projector including: a light source, the light source providing light propagating generally along a projection optical axis, the projection optical axis intersecting the device when the machine-vision head is in operation; a projection pattern element that spatially modulates the light and located so that the projection optical axis intersects the projection pattern element; and a pattern projector imaging element located so that the projection optical axis intersects the pattern projector imaging element; and (b) an imager, the imager having a reception optical axis, the reception optical axis intersecting the device when the machine-vision head is in operation, the imager maintained in a

substantially fixed relationship to the pattern projector, the imager including at least three lines of semiconductor imaging pixels; wherein a major plane of the projection pattern element, a major plane of the pattern projector imaging element, and a third plane are tilted one to another to substantially satisfy Schiempflug's condition that these three planes intersect at substantially one line.

A249. Some embodiments include the machine-vision head of alpha-numbered paragraph A248, wherein the third plane contains the reception optical axis or lies substantially parallel to the reception optical axis.

A250. Some embodiments include the machine-vision head of alpha-numbered paragraph A248, wherein the projection pattern element is maintained in a substantially fixed relationship to both the pattern projector and the imager when the machine-vision head is in operation.

A251. Some embodiments include the machine-vision head of alpha-numbered paragraph A2481, wherein the pattern projection element includes a pattern whose intensity along a line segment varies as a sine wave.

A252. One embodiment of the invention includes a machine-vision system for inspecting a device, including: (1) an inspection station, the inspection station including: (a) a pattern projector, the pattern projector including a light source, the light source providing light propagating generally along a projection optical axis, the projection optical axis intersecting the device when the inspection station is in operation, a projection pattern element that spatially modulates the light and located so that the projection optical axis intersects the projection pattern element, and a pattern projector imaging element located so that the projection optical axis intersects the pattern projector imaging element; and (b) an imager, the imager having a reception optical axis, the reception optical axis intersecting the device when the inspection station is in operation, the imager maintained in a substantially fixed relationship to the pattern projector, the imager including at least three lines of semiconductor imaging pixels; wherein a major plane of the projection pattern element, a major plane of the pattern projector imaging element, and a third plane are tilted one to another to substantially satisfy Schiempflug's condition that these three planes intersect at substantially one line, and wherein the imager provides acquired three-dimensional device geometry data regarding the device; (2) a comparator coupled to the imager,

the comparator comparing one or more characteristics of the acquired three-dimensional device geometry data with an intended predetermined geometry to produce a signal indicative of any device geometry departure of an actual device geometry from the intended predetermined geometry.

A253. Some embodiments include the system of alpha-numbered paragraph A252, wherein the third plane contains the reception optical axis or lies substantially parallel to the reception optical axis.

A254. Some embodiments include the system of alpha-numbered paragraph A252, wherein the projection pattern element is maintained in a substantially fixed relationship to both the pattern projector and the imager when the inspection station is in operation.

A255. Some embodiments include the system of alpha-numbered paragraph A252, wherein the pattern projection element includes a pattern whose intensity along a line segment varies as a sine wave.

A256. One embodiment of the invention includes a method for high-speed scanning phase measurement of a device at a machine-vision station to acquire physical information associated with the device, the method including: projecting light generally along a projection optical axis, the projection optical axis intersecting the device; spatially modulating the light with a projection pattern located so that the projection optical axis intersects the projection pattern; and imaging the spatially modulated light onto the device; and receiving light reflected from the device along a reception optical axis with an imager maintained in a substantially fixed relationship to the projected spatially modulated light, the imager including at least three lines of semiconductor imaging pixels, the reception optical axis intersecting the device; generating data representing acquired three-dimensional device geometry data regarding the device from signals from the imager; wherein spatially modulating and imaging the spatially modulated light provide a light pattern that is focused along a region of a third plane, wherein one of the at least three lines of semiconductor imaging pixels lies substantially within the third plane, and wherein a plane associated with the spatially modulating and a plane associated with the imaging the spatially modulated light, and a third plane are tilted one to another to substantially satisfy Schiempflug's

condition that these three planes intersect at substantially one line, and wherein the reception optical axis lies within the third plane or is substantially parallel to the third plane.

A257. Some embodiments include the method of alpha-numbered paragraph A256, wherein spatially modulating includes modulating with a pattern whose intensity along a line segment varies as a sine wave.

A258. Some embodiments include the method of alpha-numbered paragraph A256, further including comparing the acquired three-dimensional device geometry data with an intended predetermined geometry to produce a signal indicative of any device geometry departure of an actual device geometry from the intended predetermined geometry; and controlling a manufacturing operation of the device to compensate for the device-geometry departure.

A259. One embodiment of the invention includes a machine-vision head for inspecting a device, including: (a) a pattern projector, the pattern projector including: a light source, the light source providing light propagating generally along a projection optical axis, the projection optical axis intersecting the device when the machine-vision head is in operation; a projection pattern element that spatially modulates the light and located so that the projection optical axis intersects the projection pattern element; and a pattern projector imaging element located so that the projection optical axis intersects the pattern projector imaging element; and (b) an imager, the imager having a reception optical axis, the reception optical axis intersecting the device when the machine-vision head is in operation, the imager including: at least three lines of semiconductor imaging pixels; and a telecentric imaging element that focusses an image of the device onto the at least three lines of semiconductor imaging pixels.

A260. One embodiment of the invention includes a method for high speed, scanning phase measurement of a device at a machine-vision station to acquire physical information associated with the device, the method including: projecting light generally along a projection optical axis, the projection optical axis intersecting the device when the machine-vision head is in operation; spatially modulating the light with a projection pattern located so that the projection optical axis intersects the projection pattern; imaging the spatially modulated light onto the device; receiving light reflected from the device into an imager, the imager having a reception optical axis, the reception optical axis intersecting the device, the imager maintained in a substantially fixed

relationship to the pattern projector, the imager including three lines of semiconductor imaging pixels, wherein receiving includes telecentrically focussing an image of the device onto the at least three lines of semiconductor imaging pixels; and generating data representing acquired three-dimensional device geometry data regarding the device.

A261. Some embodiments include the method of alpha-numbered paragraph A260, further including: comparing the acquired three-dimensional device geometry data with an intended predetermined geometry to produce a signal indicative of any device geometry departure of an actual device geometry from the intended predetermined geometry; and controlling a manufacturing operation of the device to compensate for the device geometry departure, and wherein spatially modulating includes modulating with a projection pattern whose intensity along a line segment varies as a sine wave.

A262. Some embodiments include the method of alpha-numbered paragraph A260, further including: blocking an infra-red component of the light.

A263. One embodiment of the invention includes a machine-vision head for inspecting a device, including: (a) a pattern projector, the pattern projector including a light source, the light source providing light propagating generally along a projection optical axis, the projection optical axis intersecting the device when the machine-vision head is in operation, a projection pattern element that spatially modulates the light and located so that the projection optical axis intersects the projection pattern element, and a telecentric pattern projector imaging element that focusses an image of projection pattern element onto the device when the machine-vision head is in operation, and located so that the projection optical axis intersects the pattern projector imaging element; and (b) an imager, the imager having a reception optical axis, the reception optical axis intersecting the device when the machine-vision head is in operation.

A264. Some embodiments include the machine-vision head of alpha-numbered paragraph A263, wherein the imager further includes at least three lines of semiconductor imaging pixels, and wherein a major plane of the projection pattern element, a major plane of the pattern projector imaging element, and a third plane are tilted one to another to substantially satisfy Schiempflug's condition that these three planes intersect at substantially one line.

A265. One embodiment of the invention includes a machine-vision system for inspecting a device, the device having a first side and a second side, the machine-vision system including: a first inspection station for inspecting a first side of a device; a second inspection station for inspecting a second side of a device; and a tray-transfer device that operates to move the device from the first inspection station to the second inspection station, the tray-transfer device further including an inverting mechanism that operates to invert the device so that the first second side of the device can be inspected at the first inspection station and the second side of the device can be inspected at the second inspection station.

A266. Some embodiments include the system of alpha-numbered paragraph A265 wherein the inverting mechanism is positioned between the first inspection position and the second inspection position.

A267. Some embodiments include the machine-vision system of alpha-numbered paragraph A265 wherein the inverting mechanism further includes a mechanism for flipping the devices carried in a tray, the mechanism further including: a first jaw having a surface for receiving a first tray; a second jaw having a surface for receiving a second tray; a mover for moving the first jaw, the first tray having a plurality of devices, the second tray, and the second jaw into engagement with each other, the first tray associated with the first jaw and the second tray associated with the second jaw; and a rotator for rotating the first and second jaw.

A268. Some embodiments include the machine-vision system of alpha-numbered paragraph A267 wherein the mover moves the first jaw in a direction substantially perpendicular to the surface for receiving a tray associated with the first jaw.

A269. Some embodiments include the machine-vision system of alpha-numbered paragraph A267 wherein the mover moves the first jaw and the second jaw in a direction substantially perpendicular to the surface for receiving a tray associated with the first jaw.

A270. Some embodiments include the machine-vision system of alpha-numbered paragraph A267 wherein the inverting mechanism moves the plurality of devices to the second tray such that the second sides of a plurality of devices are presented for inspection.

A271. Some embodiments include the machine-vision system of alpha-numbered paragraph A267 wherein the rotator of the inverting mechanism moves the plurality of devices to the second tray such that the second sides of a plurality of devices are presented for inspection.

A272. Some embodiments include the machine-vision system of alpha-numbered paragraph A271 wherein the mover of the inverting mechanism is adapted to place the plurality of devices in the second tray at the second inspection station.

A273. Some embodiments include the machine-vision system of alpha-numbered paragraph A272 wherein the tray transfer device includes means for moving the second inspection station with respect to the inverting mechanisim.

A274. Some embodiments include the machine-vision system of alpha-numbered paragraph A273 further including a picker for picking devices which fail inspection from the second tray.

A275. One embodiment of the invention includes a machine-vision system for inspecting a plurality of devices positioned within a plurality of device-carrying trays, the machine-vision system including: a first tray adapted to carry a plurality of devices; a second tray adapted to carry a plurality of devices; a flip station for flipping the plurality of devices carried in a first tray from a first inspection position in the first tray to a second inspection position in the second tray.

A276. Some embodiments include the machine-vision system of alpha-numbered paragraph A275 wherein the flip station further includes: a first jaw having a surface for receiving a first tray; a second jaw having a surface for receiving a tray; a mover for moving the first jaw, a first tray having a plurality of devices, a second tray, and the second jaw into engagement with each other, the first tray associated with the first jaw and the second tray associated with the second jaw; and a rotator for rotating the first and second jaw.

A277. Some embodiments include the machine-vision system of alpha-numbered paragraph A276 further including:

a first slide clamp for holding at least the first tray, the first slide clamp moving the first tray from a first inspection station to a flip station; and a second slide clamp for holding at least the second tray, the second slide clamp moving the second tray from the flip station to the second inspection station.

A278. Some embodiments include the machine-vision system of alpha-numbered paragraph A275 wherein the flip station further includes a mechanism for flipping the devices carried in a tray, the mechanism further including means for limiting the motion of the rotator.

A279. Some embodiments include the machine-vision system of alpha-numbered paragraph A276 wherein the mover moves the first jaw in a direction substantially perpendicular to the surface for receiving a tray associated with the first jaw.

A280. Some embodiments include the machine-vision system of alpha-numbered paragraph A276 wherein the mover moves the first jaw and the second jaw in a direction substantially perpendicular to the surface for receiving a tray associated with the first jaw.

A281. One embodiment of the invention includes a flipping mechanism for transferring a plurality of devices from a position in a first tray to a position in a second tray, the flipping mechanism including: a first jaw having a surface adapted to receive the first tray; a second jaw having a surface adapted to receive the second tray; a mover for moving the first jaw, the first tray, the second tray, and the second jaw into engagement with each other, the first tray associated with the first jaw and the second tray associated with the second jaw; and a rotator for rotating the first and second jaw.

A282. Some embodiments include the machine-vision system of alpha-numbered paragraph A281 wherein the mover can be controlled to remove the first tray from a first inspection surface.

A283. Some embodiments include the machine-vision system of alpha-numbered paragraph A281 wherein the mover can be controlled to place the second tray at a second inspection surface.

A284. One embodiment of the invention includes a method for acquiring physical information associated with a plurality of devices placed in a tray, the method including: inspecting a first side of a device within a first tray; removing the first tray from a first surface and placing the first tray at a flip station; moving a second tray to a position near the first tray; flipping the first tray and second tray to move the device from the first tray to the second tray and place the device in the second tray so that a second side of the device is presented in the second tray; and inspecting a second side of the device within the second tray.

A285. Some embodiments include the method of alpha-numbered paragraph A284, further including moving the second tray to a second inspection surface.

A286. One embodiment of the invention includes a machine-vision system for inspecting a plurality of devices and for inverting the plurality of devices from being positioned in a first tray, the machine-vision system including: a first jaw having a surface for receiving the first tray; a second jaw having a surface; a mover for moving the first jaw, the first tray having a plurality of devices, and the second jaw into engagement with each other, the first tray associated with the first jaw; and a rotator for rotating the first and second jaw.

A287. Some embodiments include the machine-vision system of alpha-numbered paragraph A286 further including: a first conveyer for moving the first tray having a plurality of devices therein to the first jaw; and a second conveyer for moving the first tray having a plurality of devices therein from the first jaw.

A288. Some embodiments include the machine-vision system of alpha-numbered paragraph A286 wherein the first jaw is capable of holding, in any position, a tray devoid of devices.

A289. Some embodiments include the machine-vision system of alpha-numbered paragraph A286 further including: a slider for transferring the inverted devices from the second jaw into the first tray.--

In the Claims

Please cancel claims 1-289 without prejudice, and add the following claims 290-326:

290. [New] A machine-vision head for measuring a three-dimensional geometry of a device having a surface to be measured, comprising:

a projector, the projector including:

a first light source having a projection optical axis that intersects the device;

a projection-imaging element positioned along the projection optical axis and spaced from the first light source; and

a projection-pattern element positioned between the first light source and the projection imaging element along the projection optical axis, the projection-pattern element having a repeating sine-wave light-modulation pattern as measured along a line on the projection-pattern element; and

an imager, the imager having a reception optical axis that intersects the device substantially at the projection optical axis.

291. [New] The machine-vision head according to claim 290, wherein the projection-pattern element light-modulation pattern includes a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

292. [New] The machine-vision head according to claim 291, wherein the first light source includes a elongated incandescent filament having a dimension along a longitudinal axis substantially longer than a width, wherein the longitudinal axis of the filament is substantially perpendicular to the projection optical axis and substantially parallel to the grid lines of the projection-pattern element.

293. [New] The machine-vision head according to claim 292, further comprising a projection mask having an elongated aperture having a dimension along a length axis substantially longer than a dimension along a width axis perpendicular to the length axis, and wherein the length axis is substantially parallel to the grid lines of the projection-pattern element.

294. [New] The machine-vision head according to claim 293, wherein the projection mask limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

295. [New] The machine-vision head according to claim 293, further comprising a projection-mask actuator operable to adjust a position of the projection mask.

296. [New] The machine-vision head according to claim 290, further comprising a light-intensity controller, coupled to receive intensity information regarding light output from the first light source, that outputs a control signal based on a measured intensity of light from the first light source.

297. [New] The machine-vision head according to claim 296, wherein the control signal is operatively coupled to the first light source to control light output based on the measured light intensity in a feedback manner.

298. [New] The machine-vision head according to claim 296, wherein the control signal is operatively coupled to the imager to control an amount of light received in an imaging cycle of the imager.

299. [New] The machine-vision head according to claim 290, further comprising a condensing imaging element positioned between the first light source and the projection-pattern element along the projection optical axis.

300. [New] The machine-vision head according to claim 290, further comprising a focussing reflector that substantially focusses an image of the first light source adjacent to the first light source.

301. [New] The machine-vision head according to claim 300, wherein the reception optical axis is oriented to be at substantially a right angle to a direction of scanning, and the projection optical axis is oriented to be at substantially a forty-five-degree angle to the direction of scanning.

302. [New] The machine-vision head according to claim 301, wherein a major plane of the projection-imaging element is oriented substantially perpendicular to the projection optical axis and a major plane of the projection-pattern element is oriented substantially perpendicular to the projection optical axis.

303. [New] The machine-vision head according to claim 290, further comprising a second light so3urce that directs substantially unpatterned light onto the device, the second light source being activated to obtain two-dimensional intensity data about the device from the imager.

304. [New] A machine-vision system for inspecting a device, comprising:

(1) an inspection station, the inspection station including:

(a) a projector, the projector including:

a first light source having a projection optical axis that intersects the device;

a projection-imaging element positioned along the projection optical axis and spaced from the first light source; and

a projection-pattern element positioned between the first light source and the projection imaging element along the projection optical axis, the projection-pattern element having a repeating sine-wave light-modulation pattern as measured along a line on the projection-pattern element; and

(b) an imager, the imager having a reception optical axis that intersects the device when the inspection station is in operation, the imager maintained in a substantially fixed relationship to the pattern projector, the imager including at least three lines of semiconductor imaging pixels;

(2) a scanner mechanism that moves the imager relative to the device such that different portions of the device are successively imaged by the imager, wherein the first light source is activated in conjunction with the imager to obtain three-dimensional device geometry data regarding the device; and

(3) a comparator coupled to the imager, the comparator comparing one or more characteristics of the acquired three-dimensional device geometry data with an intended predetermined geometry to produce a signal indicative of any device geometry departure of an actual device geometry from the intended predetermined geometry.

305. [New] The system according to claim 304, wherein the projection-pattern element light-modulation pattern includes a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

306. [New] The system according to claim 305, wherein the first light source includes a elongated incandescent filament having a dimension along a longitudinal axis substantially longer than a width, wherein the longitudinal axis of the filament is substantially perpendicular to the projection optical axis and substantially parallel to the grid lines of the projection-pattern element.

307. [New] The system according to claim 304, further comprising a projection mask having an elongated aperture having a dimension along a length axis substantially longer than a dimension along a width axis perpendicular to the length axis, and wherein the length axis is substantially parallel to the grid lines of the projection-pattern element.

308. [New] The system according to claim 307, wherein the projection mask limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

309. [New] The system according to claim 304, further comprising a light-intensity controller, coupled to receive intensity information regarding light output from the light source, that outputs a control signal based on a measured intensity of light from the light source, wherein the control signal is operatively coupled to the imager to control an amount of light received in an imaging cycle of the imager.

310 . [New] The system according to claim 304, further comprising a focussing reflector that substantially focusses an image of the light source adjacent to the light source.

311. [New] The system according to claim 304, further comprising a condensing imaging element positioned between the first light source and the projection-pattern element along the projection optical axis.

312. [New] The system according to claim 304, wherein a major plane of the projection-imaging element is oriented substantially perpendicular to the projection optical axis and a major plane of the projection-pattern element is oriented substantially perpendicular to the projection optical axis.

313. [New] The system according to claim 304, further comprising a second light source that directs substantially unpatterned light onto the device, the second light source being activated in conjunction with the imager to obtain two-dimensional intensity data about the device from the imager.

314. [New] A method for measuring a three-dimensional geometry of a device having a surface to be measured, comprising:

projecting patterned light having a spatial-modulation pattern; the projecting pattern light including:

projecting substantially unpatterned light;

spatially modulating the unpatterened light with a sine-wave spatial modulation pattern to produce spatial-modulation patterned light; and

imaging the spatial-modulation patterned light onto the device;

scanning the device within the spatial-modulation patterned light; and

receiving reflected light from the device into at least three linear imager regions.

315. [New] The method according to claim 314, wherein the spatially modulating includes modulating with a repeating pattern of grid lines having substantially constant density along lines in a direction parallel to the grid lines and a sine-wave density along lines in a direction perpendicular to the grid lines.

316. [New] The method according to claim 315, wherein the projecting substantially unpatterned light source includes a elongated light beam, wherein a longitudinal axis of the beam is perpendicular to the direction of projection and parallel to the grid lines.

317. [New] The method according to claim 315, further comprising projection masking to an elongated aperture having a length axis substantially greater that a width axis, and wherein the length axis is substantially parallel to the grid lines of the pattern.

318. [New] The method according to claim 317, wherein the projection masking limits the projected light to less than about three sine-wave cycles of the sine-wave pattern.

319. [New] The method according to claim 317, further comprising a adjusting a position of the projection masking.

320. [New] The method according to claim 314, further comprising generating a light-intensity control signal based on intensity information regarding the projected light.

321. [New] The method according to claim 321, further comprising controlling a light source to control light output based on the measured light intensity in a feedback manner.

322. [New] The method according to claim 320, further comprising controlling an imager to control an amount of light received in an imaging cycle of the imager.

323. [New] The method according to claim 314, further comprising condensing light onto the projection-pattern along the projection optical axis.

324. [New] The method according to claim 314, further comprising reflectively focussing to substantially focus an image of the light source adjacent to the light source.

325. [New] The method according to claim 314, wherein the reception optical axis is oriented to be at substantially a right angle to a direction of scanning, and the projection optical axis is oriented to be at substantially a forty-five-degree angle to the direction of scanning.

326. [New] A computer-readable medium having computer-executable instructions thereon to cause a suitably configured information-handling system to perform the method according to claim 314.

Remarks

Applicant has amended the specification starting on page 59 to include text equivalent to the cancelled claims 1-289. New claims 290-326 (37 claims are now pending) have been added, where claims 290-325 are supported by original claims 1-36 and claim 326 is supported at page 34 lines 22-23. No new matter is added.

The Examiner is invited to call Applicant's Attorney, Charles Lemaire at 612-373-6949 if there are any questions.

Respectfully submitted,

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